DEPARTMENT OF THE NAVY
COMMANDER
NAVAL METEOROLOGY AND OCEANOGRAPHY COMMAND
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NAVMETOCCOMINST 3140.4C
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NAVMETOCCOM INSTRUCTION 3140.4C

From: Commander, Naval Meteorology and Oceanography Command

Subj: ATMOSPHERIC TURBULENCE AND ICING CRITERIA

Ref: (a) NAVMETOCCOMINST 3142.1A (Procedures Governing PIREPS)
(b) NAVMETOCCOMINST 3143.1F (TAF Code)

Encl: (1) Turbulence Reporting Criteria Table
(2) Aircraft Icing Reporting Table

1. Purpose. To set forth a common set of criteria describing the meteorological characteristics with which the respective classes of turbulence and icing are typically associated and reported (references (a) and (b)), in order that weather forecasters may uniformly evaluate and disseminate degrees of atmospheric turbulence and icing. This instruction has been completely revised and should be reviewed in its entirety.

2. Cancellation. NAVOCEANCOMINST 3140.4B

3. Action. Naval Meteorology and Oceanography Command and Marine Corps weather activities shall adopt as a standard the turbulence criteria in enclosure (1) and the aircraft icing reporting table in enclosure (2). Activities are encouraged to reproduce enclosures (1) and (2) for further dissemination as necessary for the information and guidance of personnel engaged in supporting aircraft operations.

4. Concurrence. This instruction has the concurrence of the Commandant of the Marine Corps. Marine Corps weather activities shall take such actions prescribed in this instruction which are not contradictory to specifically expressed policies of the Commandant of the Marine Corps.

5. Icing Discussion. Icing interferes with the control of aircraft by increasing drag and weight while decreasing lift. Engine-system icing reduces the effective power of aircraft engines. Some aircraft have limited or no deicing capability and; therefore, must avoid icing conditions at all times.

a. Icing Types

(1) **Rime.** Ice formed by the instantaneous freezing of small, supercooled droplets. As the drops freeze upon striking an aircraft, they trap air, producing a rough, brittle, milky opaque ice.

(2) **Clear.** Glossy, clear or translucent ice formed by the relatively slow freezing of large supercooled droplets. The droplets spread out over the airframe surface before completely freezing. Clear ice adheres firmly to exposed surfaces, and is much more difficult to remove with deicing equipment than rime ice. Since it is transparent, clear icing may go undetected until it is too late for deicing equipment to remove it. When clear ice mixes with snow, sleet, or small hail, it may become rough, irregular, and whitish.

(3) **Mixed.** This is a combination of rime and clear icing. It forms when snow or ice particles become embedded in clear ice. Mixed icing has a very rough appearance.

(4) **Frost.** Frost is light, feathery deposits of ice crystals that form when water vapor contacts a cold surface. It may occur when an aircraft descends through a cold layer of air into a layer of warm, moist air. It may also form at flight level when an aircraft passes from a subfreezing air mass into a moist and slightly warmer air mass. In addition, frost occurs on the ground and on the upper surfaces of parked aircraft during a clear night with subfreezing temperatures.

b. Rate of Accumulation. Four factors influence the rate of ice accumulation on an aircraft:

(1) **Amount of Liquid Water.** Ice formation is more rapid in cloud formations that are thick and continuous, due to the large quantities of supercooled liquid water in these clouds.

(2) **Droplet Size.** The rate of ice formation increases with cloud droplet size. As aircraft move, they push or deflect the air. The faster they fly the stronger the air flow across their surfaces. When aircraft pass through clouds or precipitation, small water droplets tend to move with the deflected air stream and not collect on the aircraft wing or structural parts. Larger supercooled droplets resist the deflecting influence and strike the aircraft causing ice to form.

(3) **Airspeed.** The rate of ice formation increases with the airspeed of the aircraft. However, at very high speeds, such as those attained by jet aircraft, friction creates enough heat on the skin of the aircraft to melt structural ice. Icing is seldom a problem at airspeeds in excess of 575 kts. Helicopter rotor speeds of 570 to 575 kts at helicopter cruise speeds preclude ice buildup on the outboard portion of the main rotor blades. The chance of ice buildup, however, increases inboard toward the rotor disk.

(4) **Aircraft Size and Shape.** The rate of ice formation varies with the size, shape and smoothness of aircraft surfaces and airfoils. Ice accumulates faster on large non-streamlined aircraft with rough surface features than it does on thin, smooth, highly streamlined aircraft. However once ice forms, the rate of ice formation accelerates, since the accumulated ice presents a larger surface area upon which droplets can freeze and collect.

c. Icing Intensities. See enclosure (2)

d. Occurrences of Icing. The atmospheric distribution of icing depends on temperature and cloud structures, which vary with altitude, synoptic situation, season, location and terrain.

(1) **Icing and Temperature.** Aircraft icing generally occurs between the freezing level and -22°C. Please note that the aircraft skin temperature must be ≤0°C. Icing can also occur at temperatures as cold as -42°C in the upper parts of cumulonimbus clouds. The type and amount of ice varies with each type of cloud:

Stratiform. Stable air masses often produce stratiform clouds with extensive areas of continuous icing conditions. The icing typically occurs in layers of 3000 to 4000 ft and is found at elevations where the temperatures range from -1°C to -15°C. It normally forms as rime type icing. High-level stratiform clouds contain mostly ice crystals and produce little or no icing.

Cumuliform. The zone of icing in cumuliform clouds is smaller horizontally but greater vertically than in stratiform clouds. In general, consider clear icing at flight altitudes where the temperatures vary from 0°C to -8°C, mixed from -9°C to -15°C, and rime from -15°C to -22°C. Clear and mixed icing will extend to greater vertical levels in the updraft (lifts larger supercooled droplets) and in the anvils of building to mature cumulonimbus clouds.

(2) **Icing in Relation to Fronts.** Fronts provide the lifting mechanism to form clouds and are therefore concentrated areas for icing. All types and intensities are encountered and are dependent on the instability aloft, speed, and slope of the front. Overrunning warm fronts and shallow cold fronts are extremely hazardous as they may generate large areas of freezing rain/drizzle. Severe clear icing is often associated with this situation.

(3) **Icing in Relation to Terrain.** Icing is more likely and more severe in clouds over mountainous regions than over other terrain. Strong upslope flow on the windward side of a range can lift large water droplets as much as 5,000 ft into subfreezing layers above a peak, resulting in supercooled water droplets. In addition, if a frontal system moves across a mountain range, the normal frontal lift combines with the orographic effects to create extremely hazardous icing zones.

6. <u>Turbulence Discussions</u>. Turbulence classification/forecasting has always been a challenge. The difficulty arises because factors creating turbulence in one instance may not cause turbulence in another similar situation. Complicating matters further is the fact that while one aircraft may report "smooth sailing," minutes later, another aircraft flying through the same airspace may report significant turbulence. Turbulence can rip an aircraft apart in flight, damage the airframe, and cause

injury. Therefore, accurate turbulence reports are an important part of aviation weather.

a. Turbulence Classifications. See enclosure (1)

(1) **Light:** An aircraft experiences slight, erratic change in attitude and/or altitude. It usually produces a slight variation in airspeed of 5-14 kts with a vertical gust velocity of 5-19 ft per second. Loose objects in aircraft remain at rest. Light turbulence may be found in many areas, such as:

(a) In mountainous areas, even with light winds.

(b) In and near cumulus clouds.

(c) Near the tropopause.

(d) At low altitudes in rough terrain when winds exceed 15 kts.

(2) **Moderate:** The aircraft experiences moderate changes in attitude or altitude, but remains in positive control at all time. There are usually small variations in airspeed of 15-24 kts; vertical gust velocity is 20-35 ft per second. Occupants feel definite strains against seat restraints. Unsecured objects in aircraft are dislodged. Moderate turbulence may be found:

(a) In mountain waves as far as 300 miles leeward a ridge, when the wind perpendicular to the ridge exceeds 50 kts.

(b) In towering cumuliform clouds and thunderstorms.

(c) Within 100 nm of the jet stream on the cold air side.

(d) At low altitudes in rough terrain when the surface winds exceed 25 kts.

(3) **Severe:** The aircraft experiences abrupt changes in attitude or altitude and may be out of control for short periods. There are usually large variations in airspeed $\geq$ 25 kts and the vertical gust velocity is 36-49 ft per second. Occupants thrown violently against seat restraints. Unsecured objects in aircraft are tossed about. Severe turbulence occurs:

(a) Up to 150 miles leeward of the ridge and within 5,000 ft of the tropopause when a mountain wave exists and winds perpendicular to the ridge exceed 50 kts.

(b) In and near mature thunderstorms.

(c) Near jet stream altitude and about 50 to 100 miles on the cold air side of the jet core.

(4) **Extreme:** The aircraft is violently tossed about and practically impossible to control. Structural damage may occur. Rapid fluctuations in airspeed are the same as severe turbulence ($\geq$ 25 kts) and the vertical gust velocity is $\geq$ 50 ft per second. Though extreme turbulence is rarely encountered, it is usually found in the strongest forms of convection and wind shear. The two most frequent locations of extreme turbulence are:

(a) In mountain waves in or near the rotor cloud.

(b) In severe thunderstorms, especially in organized squall lines.

b. Aircraft Turbulence Sensitivities. Different types of aircraft have different sensitivities to turbulence. An aircraft's sensitivity varies considerably with its weight (amount of fuel, cargo, munitions), air density, wing surface area, wing sweep angle, airspeed, and aircraft flight "attitude." Generally, the following conditions **increase** the effects of turbulence:

(1) **For fixed-wing aircraft:**

(a) Decreased weight of aircraft.

(b) Decreased air density (increased altitude).

(c) Increased wing surface area.

(d) Decreased wing sweep angle (wings more perpendicular to fuselage).

(e) Increased airspeed.

(f) Non-level flight.

(2) **For rotary-wing aircraft:**

(a) Directly proportional to the speed of the aircraft.

(b) Inversely proportional to the weight of the aircraft.

(c) Inversely proportional to the lift velocity (the faster the liftoff, the less the turbulence).

(d) Directly proportional to the arc of the rotor blade (the longer the blade, the greater the turbulence).

Since aircraft sensitivity to turbulence varies considerably, use caution when applying forecast turbulence to a specific aircraft type, configuration, and mission profile.

c. Types. There are four types of turbulence, thermal and mechanical.

(1) **Thermal Turbulence.** This type is associated with surface heating. As solar radiation heats the surface, the air above it is warmed through thermal convection within the boundary layer. The warm air rises in an uneven and irregular motion, creating eddies and gusts--turbulence.

(2) **Mechanical Turbulence.** This type is caused by horizontal and vertical wind shear and is the result of pressure gradient differences, terrain obstructions, or frontal zone shear. Two major types of mechanical turbulence are:

(a) **Clear Air Turbulence (CAT).** CAT includes all turbulence not associated with visible convective activity. It includes high-level frontal and jet stream turbulence. It may occur in high-level, non-convective clouds.

(b) **Mountain Wave (MV).** Mountain Wave turbulence often occur in clear air in a stationary wave downwind of a prominent mountain range. It is caused by the disturbance of the wind by the mountain range.

(3) **Wake Turbulence.** Although neither forecasted nor recorded in a TAF/PIREP, wake turbulence is a problem with the increased use of heavy aircraft. Every aircraft generates two counter-rotating vortices. Wake turbulence results when an aircraft encounters vortices from another aircraft. Vortex *generation* begins when the nose wheel breaks deck/ground and ends when the nose wheel is back on the deck/ground again during landings. A vortex forms at a wingtip as air circulates outward, upward, and around the wingtip. The diameter of the vortex core varies with the size and weight of the aircraft. They can be 25 to 50 ft in diameter with a much larger area of turbulence. The vortices usually stay fairly close together (about 3/4 of the wingspan) until dissipation. They sink at a rate of 400 to 500 ft per minute and stabilize about 900 ft below the flight path, where they begin to dissipate.

(4) **Low-Level Wind Shear (LLWS).** Low-level wind shear is a change in wind speed and/or direction over a short period of time, resulting in a shearing action. It is particularly hazardous for takeoffs/landings when it happens over a short duration, effects airspeed variations of GT 10kts, and is within 2000 ft of the ground. Conditions favorable for LLWS are:

(a) Thunderstorm outflow boundaries and/or downbursts

(b) Strong frontal boundaries

(c) Low-Level jets and/or gusty surface winds

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TURBULENCE REPORTING CRITERIA TABLE

Intensity	Aircraft Reaction	Inside Aircraft	Reporting Term Definitions
Light	Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw). It usually produces slight variations in airspeed of 5 - 14 kts.	Occupants may feel a slight strain against seat belts or shoulder straps. Unsecured objects may be displaced slightly.	Occasional - Less than 1/3 of the time Intermittent - 1/3 to 2/3 of the time Continuous - More than 2/3 of the time
Moderate	Changes in altitude and/or attitude occur but the aircraft remains in positive control at all times. It usually causes small variations in indicated airspeed of 15 - 24 kts.	Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged.	CHOP: Descriptive term for turbulence rhythmic in nature or rapid bumps/jolts CAT: Clear Air Turbulence includes all not associated with convective activity.
Severe	Turbulence that causes large, abrupt changes in altitude and/or attitude. Usually causes large variations in indicated airspeed GTE 25 kts. Aircraft may be momentarily out of control.	Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about.	LLWS: Low Level Wind Shear is windshear within 2000 ft of the surface.
Extreme	Aircraft is violently tossed about and is practically impossible to control. May cause structural damage.		MV: Mountain Wave is caused by the disturbance of the wind by a mountain range.

NOTE 1: THE PILOT DETERMINES THE DEGREE OF TURBULENCE, INTENSITY, AND DURATION.

NOTE 2: PILOTS SHOULD REPORT LOCATION, ALTITUDE OR RANGE OF ALTITUDES, TYPE AIRCRAFT, AIR TEMPERATURE, INTENSITY, DURATION AND TYPE OF TURBULENCE, AND WHETHER IN CLOUDS OR CLEAR AIR.

NOTE 3: See NAVMETOCCOMINST 3142.1A for encoding procedures

AIRCRAFT ICING REPORTING TABLE

Intensity	Ice Accumulation
Trace	Ice becomes perceptible. Rate of accumulation slightly greater than sublimation. Non-hazardous, even if de-icing/anti-icing equipment is not used, unless encountered for more than an hour.
Light	Rate of accumulation may create a problem if flight is over one hour in this environment. Occasional use of de-icing/anti-icing equipment removes/prevents accumulation. Does not present a hazard if de-icing/anti-icing equipment used.
Moderate	Rate of accumulation is such that even short encounters become potentially hazardous and use of de-icing/anti-icing equipment or diversion is necessary.
Severe	Rate of accumulation is such that de-icing/anti-icing equipment fails to control or reduce the hazard. Immediate diversion is required.

TYPES OF ICING

Type	Definition
Clear	Glossy, clear or translucent ice formed by relatively slow freezing of large supercooled water droplets.
Rime	Rough, milky, opaque ice formed by instantaneous freezing of small-supercooled water droplets.
Mixed	Combinations of clear and rime icing.

NOTE 1: THE PILOT DETERMINES THE TYPE OF ICING, INTENSITY, AND DURATION.
NOTE 2: PILOTS SHOULD REPORT LOCATION, ALTITUDE OR RANGE OF ALTITUDES, TYPE AIRCRAFT, AIR TEMPERATURE, INTENSITY, AND TYPE OF ICING.
NOTE3: SEE NAVMETOCCOMINST 3142.1A FOR ENCODING PROCEDURES